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VII . 1

# EXTENSIONS OF SATURN

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**SPACE SYSTEMS CENTER – HUNTINGTON BEACH, CALIFORNIA**

# ABSTRACT

This paper discusses the possible applications of Saturn vehicles to future space exploration. Potential missions utilizing Apollo derived hardware are examined. Research, development, and operations in earth orbit as well as lunar exploration, unmanned and manned interplanetary exploration are reviewed. These hypothetical missions are discussed in the context of the present and potential capability of three configurations of the Saturn vehicle; an uprated Saturn I, a three-stage Saturn V and a four-stage Saturn V.

NOTE: Work presented herein was conducted by the Douglas Missiles and Space Systems Division under company-sponsored research and development funds. Therefore, the concepts and objectives described within this paper reflect the opinions of the authors and do not necessarily constitute endorsement by NASA, the Air Force, or any other U. S. Government organization. The nominal performance numbers presented are typical of the current configurations and possible future vehicle configurations.

# EXTENSIONS OF SATURN

## INTRODUCTION

The landing of Apollo on the lunar surface will represent the accomplishment of a major United States goal in space. It was a goal which was bravely stated and boldly pursued. The resources accumulated in accomplishing this goal will be able to serve the United States and the world in missions even more complex and perhaps ultimately more important than Apollo. These resources include launch facilities, tracking systems, vehicle propulsive techniques, important technological and manufacturing competence, knowledge of the functioning and limitations of man in space, and talent and expertise tuned to the needs of the space programs. Continued use of these Apollo products and capabilities will make it possible for the United States to pursue advanced goals without the necessity for duplicating the investment which will lead to the successful accomplishment of Apollo. The possible approaches outlined are considered to be a logical extension of current knowledge extrapolated to future space requirements.

Throughout this paper the general performance of three vehicles will be discussed. These vehicle configurations are shown in figure 1. The first is a standard three-stage Saturn V, the second is a four-stage configuration of Saturn V and uses a Centaur as a typical example of the fourth stage. The third configuration is a standard uprated Saturn I vehicle. The details of these configurations and their performance are well known. Briefly, the standard Saturn V vehicle weighs approximately 2.9 million kg (6.4 million pounds) at lift-off and can place over 118,000 kg (260,000 pounds) in earth orbit or 43,000 kg (95,000 pounds) to escape velocity. The uprated Saturn I can place 16,700 kg (37,000 pounds) in earth orbit. These vehicles will be extremely important in accomplishing future space goals.

Future activity in space can be grouped into three regimes of exploration: research, development and operations in earth orbit; unmanned and manned interplanetary exploration, and lunar exploration. We will review the possible application of Apollo-derived hardware to future missions in these three categories of space operation.

# SATURN S-IVB CONFIGURATIONS

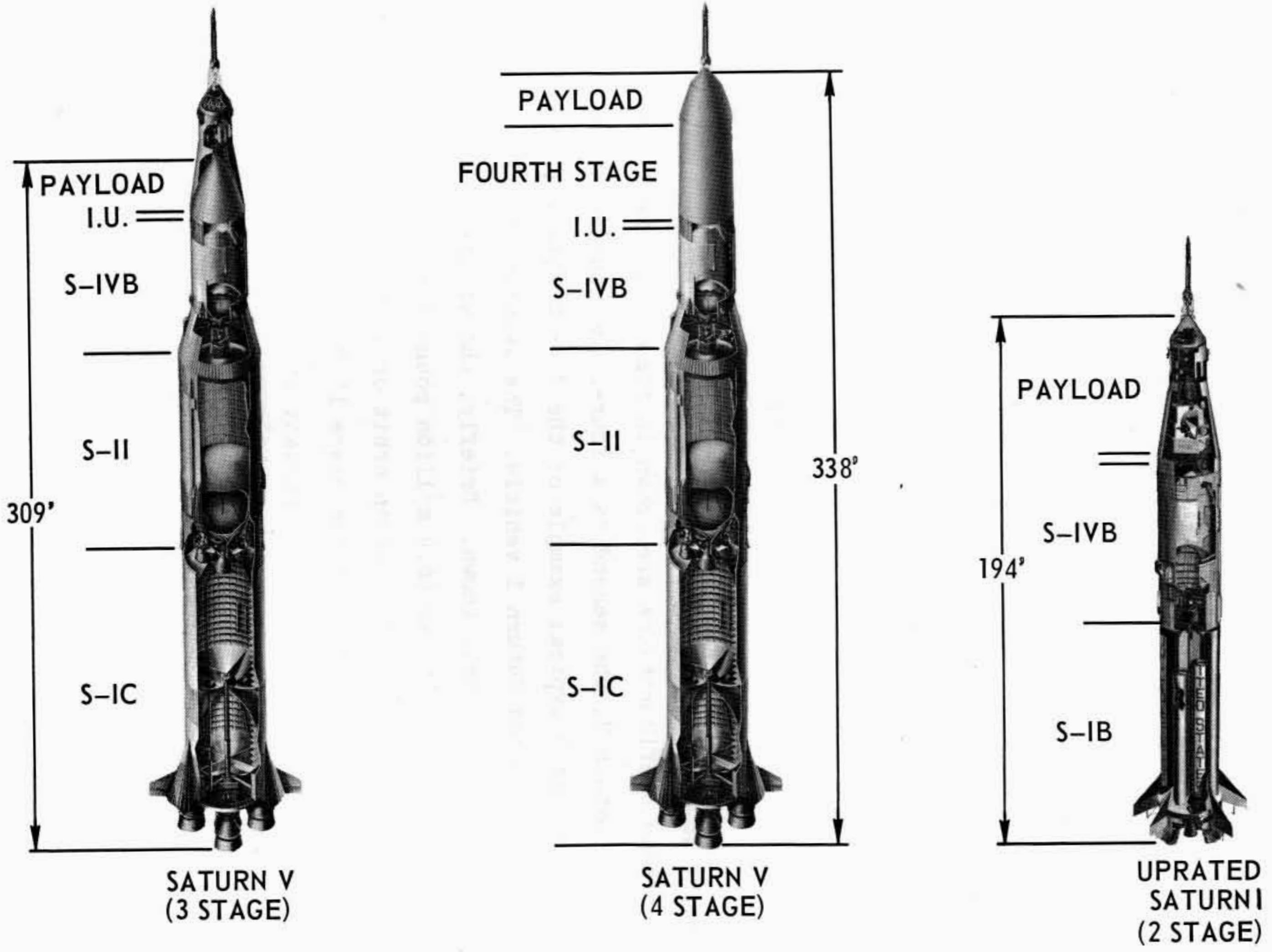


FIGURE 1

## EARTH ORBIT

The performance of the three-stage and possible four-stage configuration of Saturn V is shown in figure 2. The two-stage uprated Saturn I vehicle is summarized in figure 3. In each instance it is possible for these vehicles to achieve orbital velocity with only two stages. The uprated Saturn I can boost over 16,700 kg (37,000 pounds) to low earth orbit at low inclinations and the Saturn V, 117,500 kg (260,000 pounds). The S-IVB stage as employed in Saturn V is capable of restart. Our performance studies have shown that when higher altitudes are required, payload can be increased by first entering a low earth orbit and then accomplishing a Hohmann transfer to a higher altitude. The performance achieved in this Saturn V mission is shown in figure 4. Note in this figure that approximately 31,500 kg (70,000 pounds) can be placed to synchronous orbit using Saturn V.

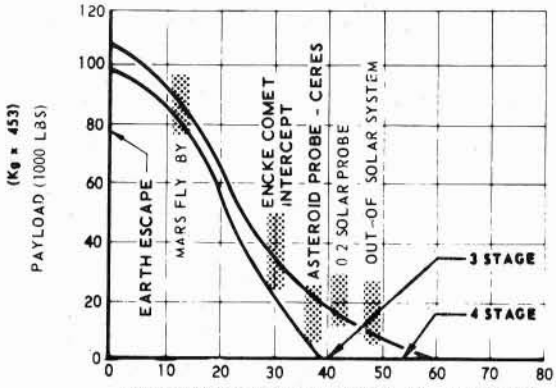
The earth escape capability of Saturn can be significantly augmented if the vehicle is used in combination with an uprated Saturn I launch. For example, if a portion of the payload is boosted to earth orbit on an uprated Saturn I and the remaining portion of the payload is launched with Saturn V, the two payloads could rendezvous and dock in earth orbit. The Saturn V/S-IVB would then provide escape energy with its second burn. While a standard Saturn V can launch 43,000 kg (95,000 pounds) to escape velocity, the rendezvous mission depicted in figure 5 can escape 54,500 kg (120,000 pounds), an increase of about 25 percent. It is significant to note that this type of mission does not require any additional hardware; rather the gain is achieved by using existing Saturn hardware in the appropriate sequence.

In certain flights of uprated Saturn I and Saturn V, in both the Apollo and follow-on programs, the upper or S-IVB stages are expected to remain in orbit after propelling primary payloads into their mission trajectory (see figure 6). Such expended or spent stages could be profitably utilized in scientific experiments, technology development, and sometimes even operational support. Thus, it appears that the expended S-IVB stages, rather than drifting unused in space, may be applied to an entirely new series of secondary applications.

Due to its large volume and other unique characteristics, the drifting S-IVB stage can provide some rather economical and useful services and accommodations

# NOMINAL SATURN V THREE & FOUR STAGE PERFORMANCE

(LAUNCH AZIMUTH 90° - ORBIT INCLINATION 28.5°)



NOTES:

1. COPLANAR DIRECT ASCENT LAUNCH FROM E.T.R.
2. PARKING ORBIT ALTITUDE = 100 N. MI.
3. $V_{\infty} = \sqrt{(V_f)^2 - (V_{esc})^2}$

WHERE:

$V_f$ = VEHICLE CUT-OFF VELOCITY INERTIAL, (FT/SEC)

$V_{esc}$ = ESCAPE VELOCITY AT A CUT-OFF ALTITUDE (FT/SEC)

$V\infty = \sqrt{C_3}$ - ENERGY PARAMETER

FIGURE 2

# NOMINAL UPRATED SATURN I PERFORMANCE

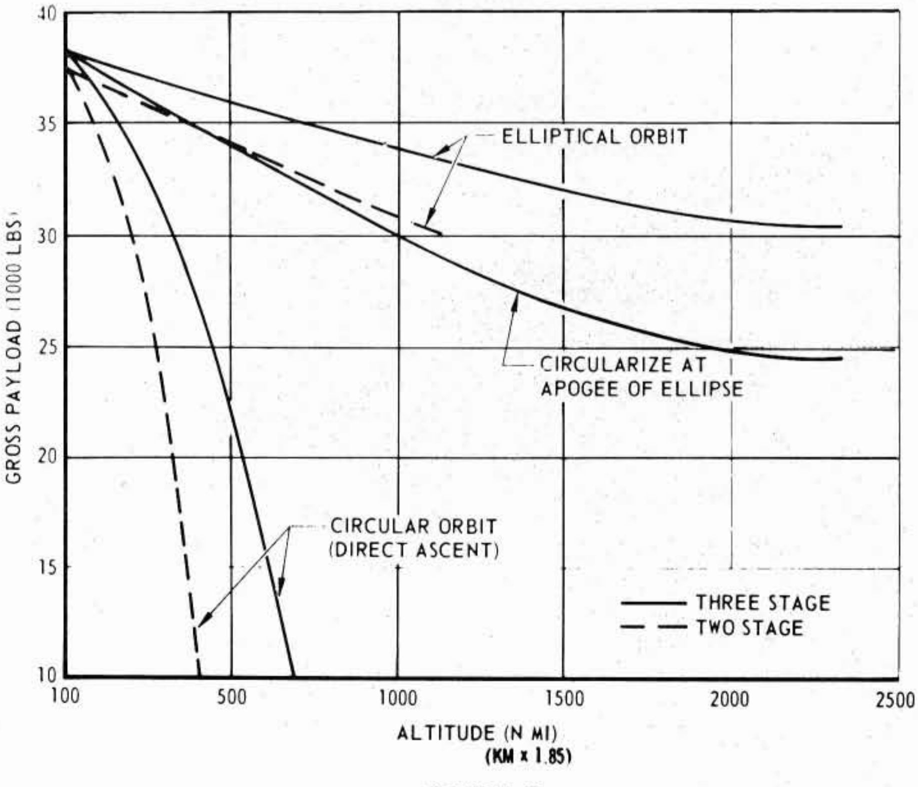


FIGURE 3

# SATURN V HOHMANN TRANSFER PAYLOAD CAPABILITY

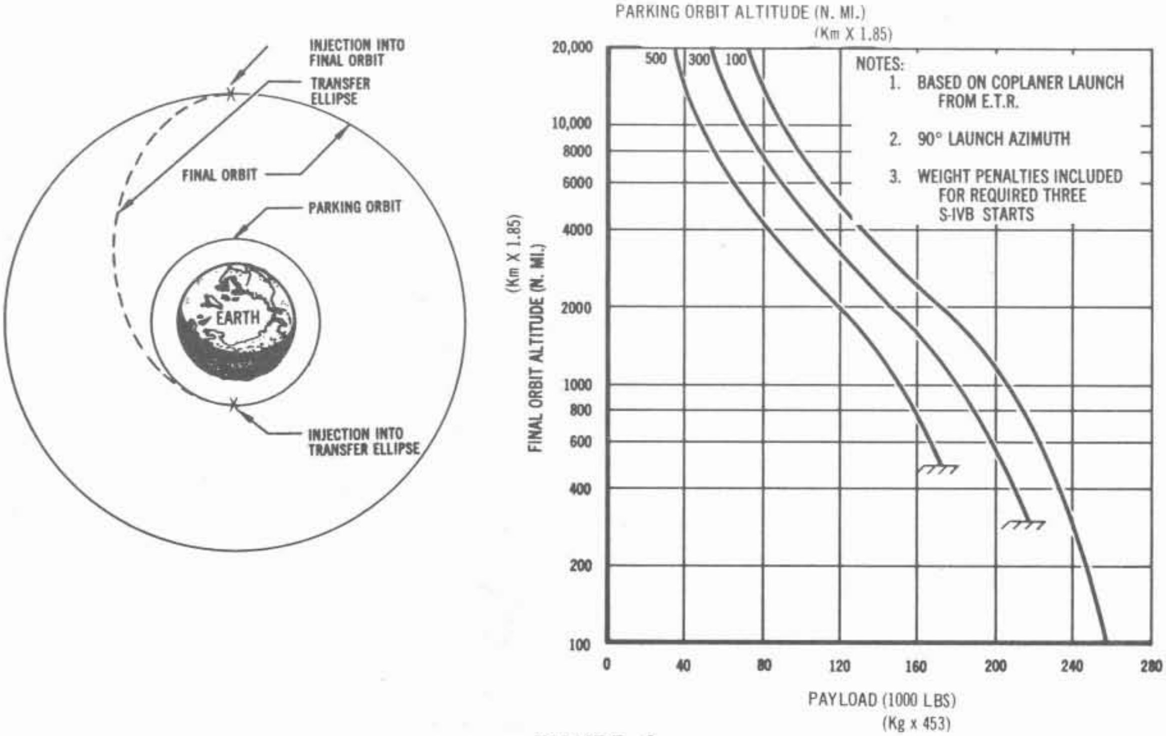


FIGURE 4

# PAYLOAD RENDEZVOUS MODE

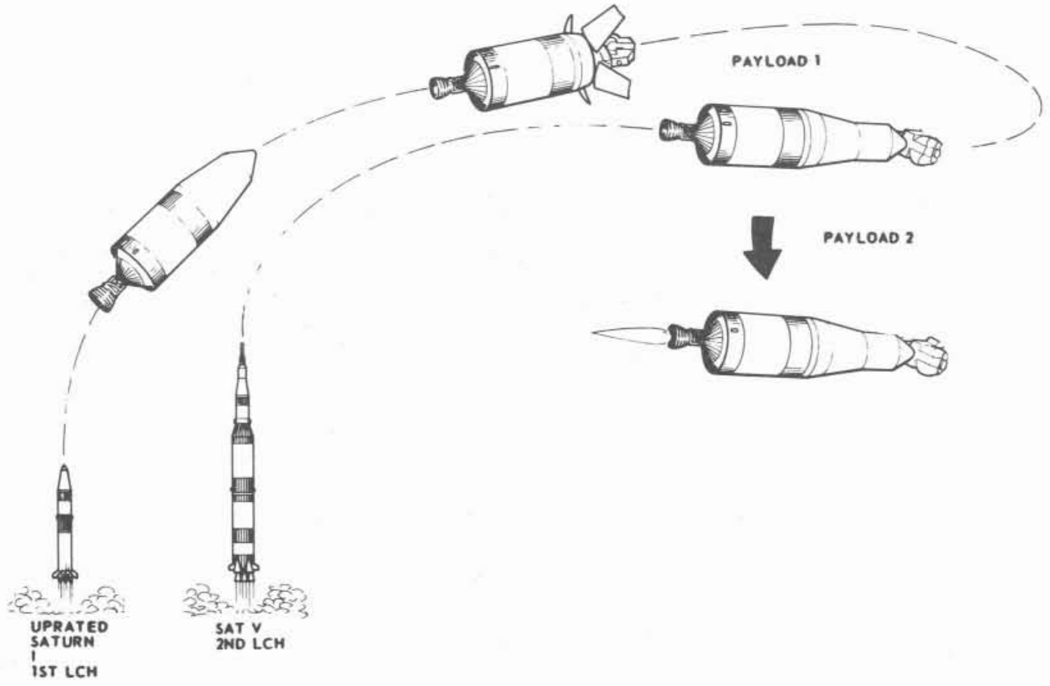


FIGURE 5

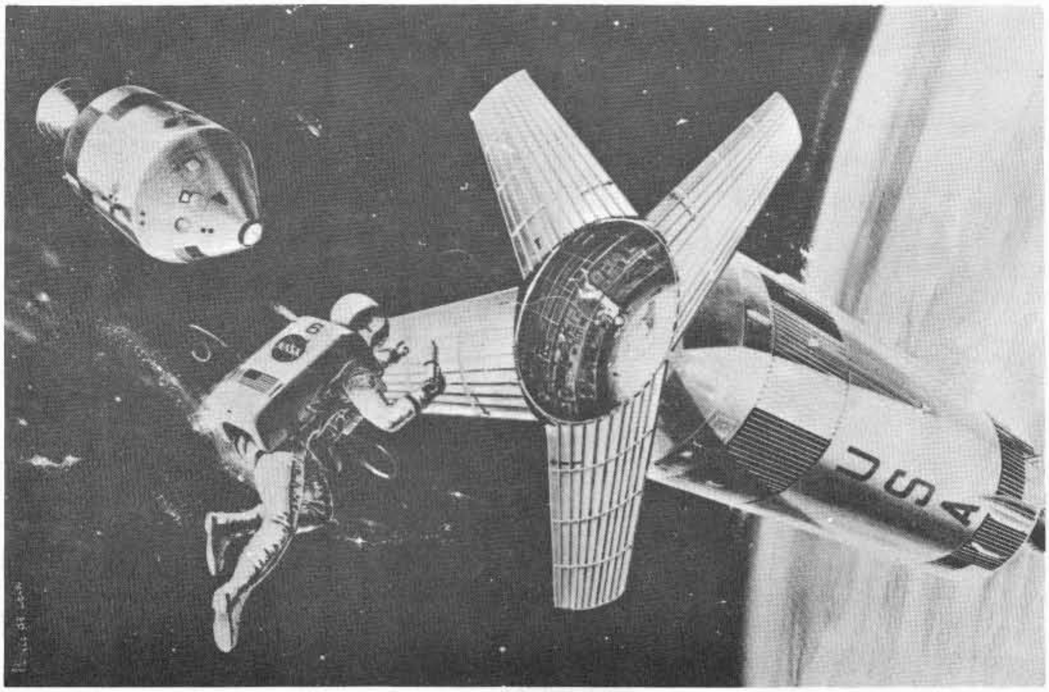


**FIGURE 6**

in space. An example of a spent S-IVB application that can be considered is an orbital rendezvous and launch technology experiment involving two S-IVB's.

Orbital Rendezvous and Launch Technology

Many of the future programs being studied involve operations such as vehicle rendezvous, docking, orbital checkout, restart, and launch. In recent years, there has been a considerable growth in interest concerning orbital assembly and reuse of vehicles for such applications as Martian Flyby, large orbital research laboratories, orbital launch facilities, and space logistics systems. Indications are that these systems will be developed subsequent to the Apollo Program in the nineteen seventies and nineteen eighties. Therefore, it is important that the various technologies involved in such future systems be at least broached or elementally developed as soon as possible.

The programs following Apollo will undoubtedly involve a great variety of science and technology experiments. In the technology area, the experiments could range from the testing of space effects on components to large scale operational experiments involving entire vehicles. Since there is considerable interest in utilizing current vehicles as much as possible to penetrate new technology and mission areas, the spent S-IVB affords an excellent experimental resource.

In view of future space system objectives, we feel that considerable research and development should be conducted in the fields of orbital rendezvous, docking, and restart; particularly the associated mechanical, hydraulic, pneumatic, electrical, and electronic interaction between vehicles in space.

A great amount of data on the basic hardware and techniques involved in orbital operations can be acquired through the joint launching and interaction of two uprated Saturn I/S-IVB stages, accompanied by a manned Apollo Command and Service Module (see figure 7). In this hypothetical experiment, the first of two uprated Saturn I vehicles used would launch an S-IVB which injects itself into orbit with approximately 8,600 kg (19,000 pounds) of residual propellants, very similar to the experiment flown on Vehicle AS-203. The second uprated Saturn would require a Command and Service Module launched to intercept the first or unmanned vehicle shortly after completion of its first orbit; similar to Gemini 7 and 6 mission. The manned vehicle would be flown to a position slightly below and ahead of the target vehicle, using full J-2 engine thrust of 885,000 newtons (200,000 pounds). Gross terminal rendezvous would be accomplished with the J-2 engine operating in an idle mode at approximately 26,500 newtons (6,000 pounds) thrust and bring the chase vehicle 90 meters (300 feet) in front of the target vehicle. Microrendezvous and docking would be accomplished with the auxiliary propulsion system of the chase vehicle under direct astronaut observation. After docking, a 453 kg/min (1,000 pounds per minute) propellant transfer experiment would be performed, followed by a J-2 engine checkout, countdown, and restart. It appears feasible to burn the J-2 engine for approximately ten seconds in such a restart. This thrust could be used to either park the vehicle in a higher orbit or perhaps deorbit it for debris control or in a recovery experiment.

Performing this kind of experiment would permit development of technology leading to stage assembly in earth orbit and technology experimentation with large scale propellant transfer, both important facets of future space operations.

# S-IVB LARGE SPACE VEHICLES

S-IVB-2215A

## RENDEZVOUS AND DOCKING

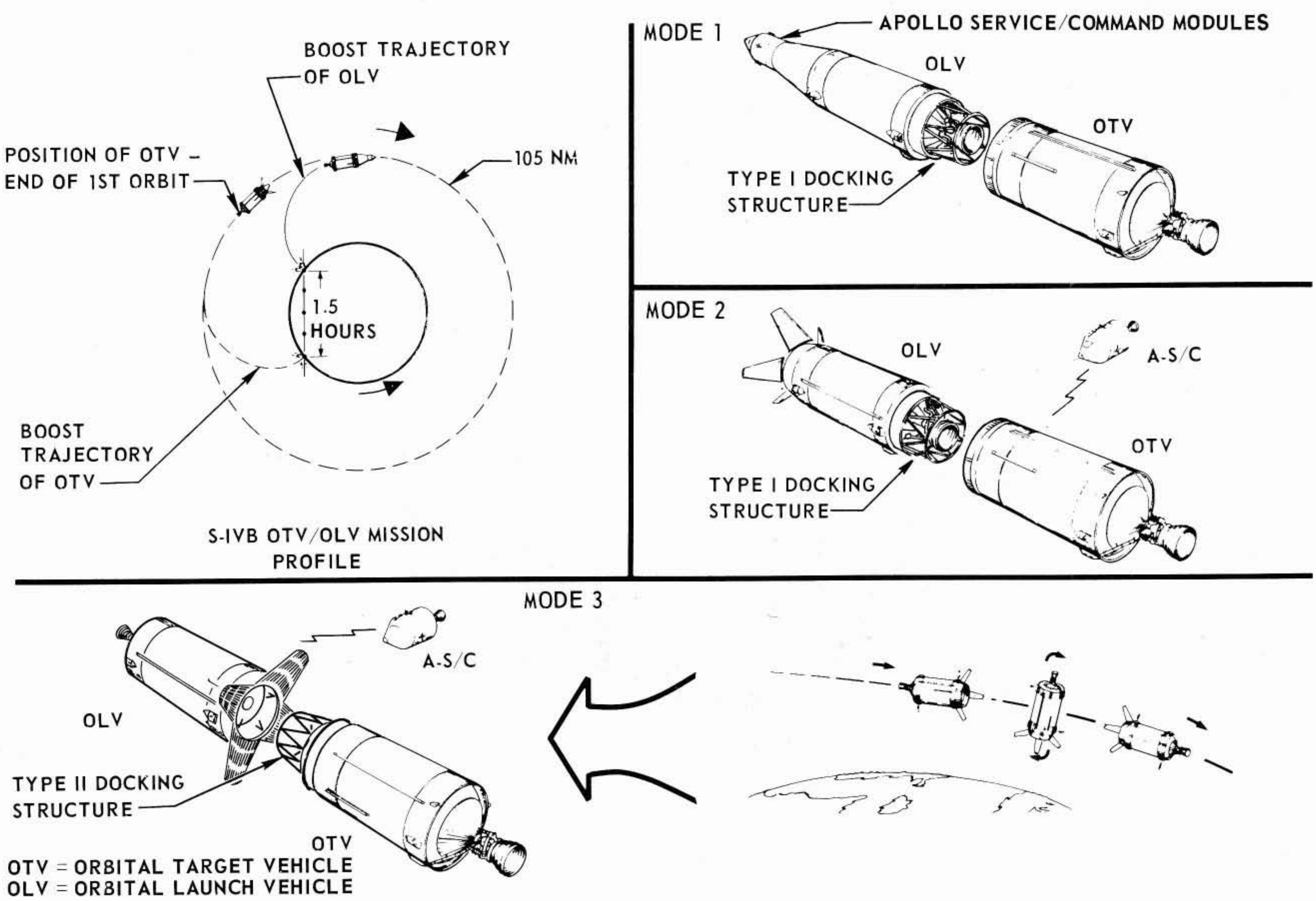


FIGURE 7

## INTERPLANETARY EXPLORATION

The Saturn vehicle family can significantly contribute in the pursuit of interplanetary goals both for manned and unmanned missions. In the case of unmanned probes, the Voyager payload for flights to Mars and Venus aboard Saturn V could be considered in the early and mid-70's. A possible configuration is shown in figure 8. Here the three-stage Saturn V is used to deliver two payloads to Mars. The payloads themselves have been conceived as flyby spacecraft which separate and monitor soft landing modules. Depending on the exact nature of the trajectory chosen, Saturn V can boost approximately 34,000 kg (75,000 pounds) of payload on a 150-day Mars trip.

### Unmanned Interplanetary Exploration

The Saturn family of vehicles can perform missions demanding even more booster energy than Voyager. We have analyzed, for example, the use of Saturn V in three-stage and four-stage modes in missions to all of the planets, the asteroids, flights toward the sun, flights out-of-the-ecliptic and beyond the solar system itself. In discussing the potential performance of this vehicle in these advanced missions, reference will be made to current configurations. The first of these included in our studies is the standard Saturn V using the Voyager shroud, shown in figure 9. The upper stage here contains about 18,200 kg (40,000 pounds) high energy propellant and has a thrust of 133,000 newtons (30,000 pounds). This stage is roughly equivalent to today's Centaur. Some possible future unmanned interplanetary missions are reviewed in turn.

### Planetary Exploration

Flights to Mars and Venus require less energy than other planets. As our interest begins to extend beyond the nearby planets, we will find trip time increasing and payload capacity of launch systems diminishing. For example, a trip to Jupiter, a particularly interesting target because of its mass, will require approximately 750 days on a simple Hohmann transfer trip trajectory. The three-stage Saturn V vehicle could deliver a 10,800 kg (24,000 pound) payload on this mission; this payload could be increased to 16,300 kg (36,000 pounds) by using a four-stage Saturn V. If payloads of this magnitude are not required, appreciably shorter

## POSSIBLE VOYAGER PAYLOAD ARRANGEMENT

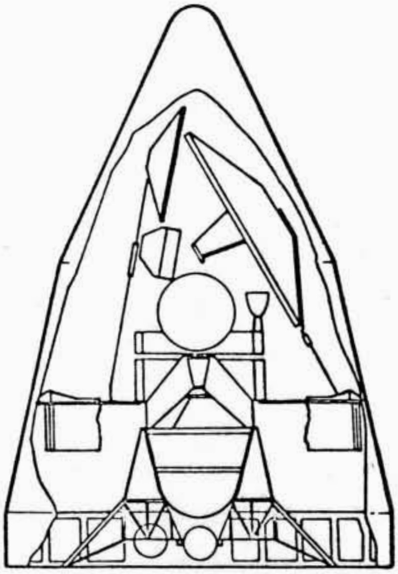


FIGURE 8

## 4th STAGE FOR SATURN V FOR DEEP SPACE MISSIONS

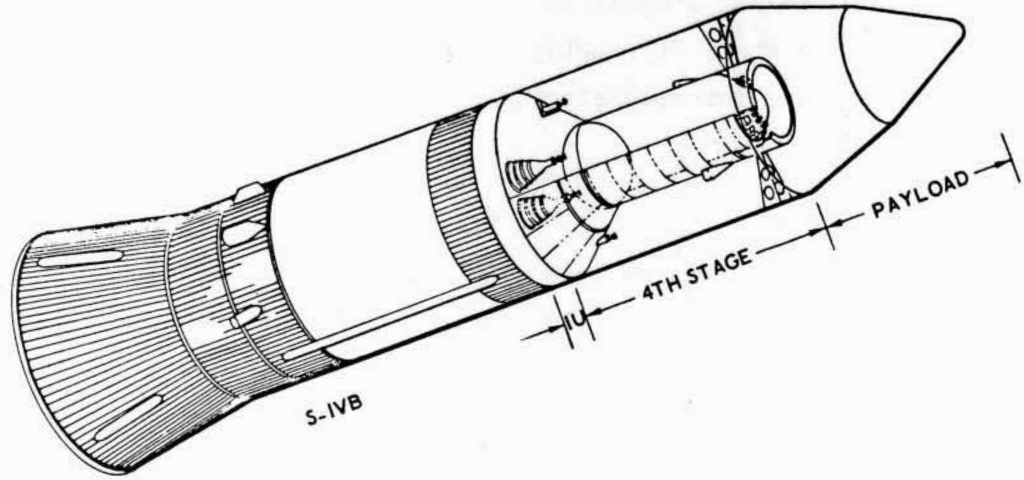


FIGURE 9

trip times can be achieved as shown in figure 10. Note that with the four-stage Saturn V configuration, the trip time can be reduced by one-half and a payload of 5,800 kg (13,000 pounds) is still available.

### Comet Intercept

Short period comets return every six or seven years and have aphelia close to Jupiter's orbit. These comets in particular will provide good targets for probe vehicles of the future because their orbits are known and their arrival times are predictable. The Comet Encke is a good choice for a comet intercept mission because it is associated with four large meteor streams and thus with a large quantity of meteoritic material. It is also the closest to earth, a bright comet, and provides time, prior to perihelion, available for data recovery. Encke has a short period which provides many launch opportunities. It should be emphasized that, en route to the comet, very valuable information can be collected on all aspects of space environment outside the plane-of-the-ecliptic.

The three-stage Saturn V can boost 10,000 kg (22,000 pounds) on an intercept trajectory with Encke and the four stage vehicle, 15,400 kg (34,000 pounds). The trip time for this mission is approximately 100 days. Particularly interesting experiments could be performed relating to the determination of the comet structure, plasma interactions, and chemical composition. For example, physical instrumentation could be employed which might confirm or refute the "icy conglomerate" model concept now thought to represent comet structure.

### Asteroid Missions

Between the orbits of Mars and Jupiter revolve thousands of small bodies called asteroids, planetoids or minor planets. Some are only a few miles or less in diameter; while Ceres, the largest, is nearly 925 km (500 miles) across.

Typical asteroid experiments would include measurement of mass distribution; optical spectrographic experiments relating to physical properties of the asteroids, chemical analysis of the particles involving thermal neutron activity, neutron capture, gamma ray analysis, gas chromatography, X-ray fluorescence, etc., to determine organic and inorganic composition of some small captured asteroids, measurement of interplanetary magnetic fields, interaction of the solar plasma

# TRIP TIME VS PAYLOAD CAPABILITY

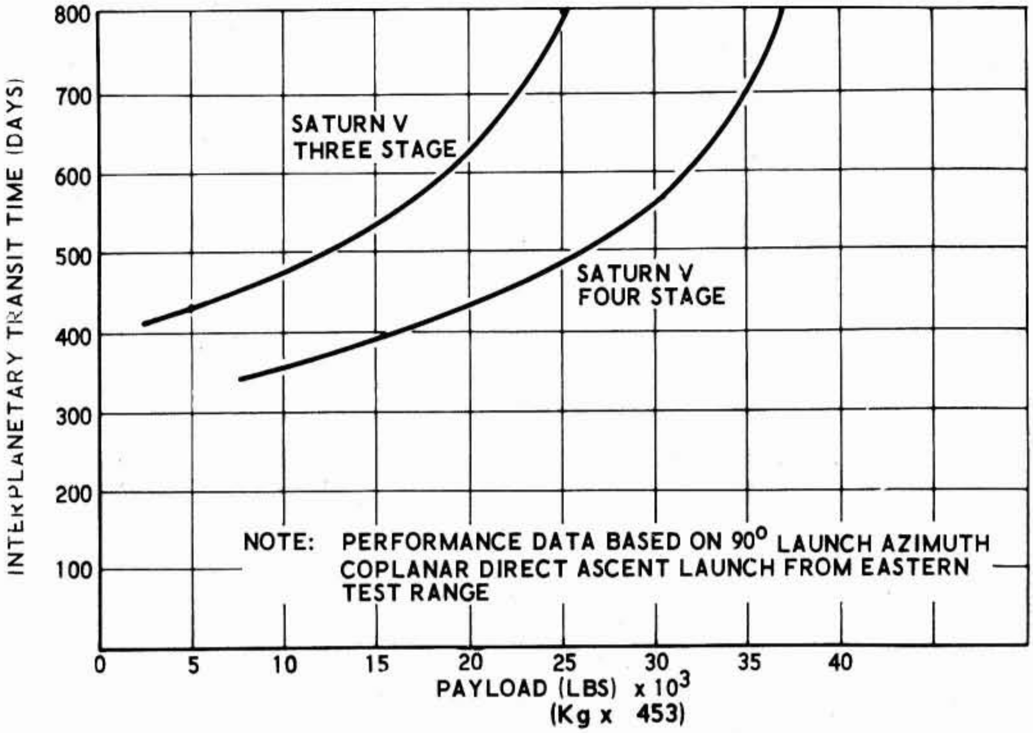


FIGURE 10

with the asteroids, equilibrium temperature in the belt. All will be of vital scientific interest. Television pictures of the asteroids may lead to greater understanding of the processes of formation of these anomolous bodies and the solar system itself. Saturn V can place a 3,200 kg (7,000 pound) payload past the asteroid Ceres and the four-stage version can boost 10,000 kg (22,000 pounds). This mission involves a trip time of 200 days.

Solar Probe

A probe toward the sun would have as its objectives the determination of:

1. Spatial and temporal variation of distribution, energy spectra, and trajectories of solar particles.
2. Type of particle matter, i.e., electrons, protons, neutrons and heavier ions.
3. The spatial and temporal variation of magnetic and electrical field strengths and directions.
4. Interactions between particles and fields.
5. Extent of the lower frequency electromagnetic radiation from the sun.

The closer a payload is placed to the surface of the sun, the more energy demanding the mission. A solar probe flown to .2 AU and boosted by a four-stage Saturn V can weigh 6,700 kg (14,000 pounds); on a mission to .12 AU, a four-stage Saturn V can boost 2,500 kg (5,500 pounds). The trip times associated with these missions are 80 and 75 days, respectively.

## Out-of-the-Ecliptic Probes

All planets orbit in planes that are inclined less than 7 degrees from the ecliptic plane except Pluto which is inclined 17 degrees. To date, scientific missions have been limited to near the ecliptic plane. Space exploration into higher inclined orbits (out-of-the-ecliptic) are most desirable, but higher boost velocities are required.

An out-of-the-ecliptic probe would determine whether solar phenomena, such as the solar wind, possess spherical symmetry or are confined chiefly to the plane of the ecliptic. The probe will measure solar phenomena, including solar storms, electromagnetic and electrostatic fields, high energy particles and perhaps, X and Gamma Ray measurements toward and away from the sun. By making these measurements in a plane inclined significantly out-of-the-ecliptic ($10^\circ$ - $45^\circ$), a third dimension would be added to our knowledge of solar system physics.

If the mission were defined as requiring an orbital trajectory inclination 30° to the ecliptic with a radius from the sun equal to that of the earth's orbital radius, a payload of about 545 kg (1,200 pounds) could be boosted by the four-stage Saturn V. The mission is quite sensitive to inclination angle and if the mission is flown at 25° inclination, payload will rise to 5,450 kg (12,000 pounds).

## Exploration of Earth/Moon Libration Points

Stable gravitational points exist between two planetary bodies. These points, known as the $L_4/L_5$ "Trojan" points, are established by the restricted three body gravity case. The most interesting examples of natural bodies that occupy points $L_4$ and $L_5$ are the "Trojan" asteroids, which are in the Sun-Jupiter system. For the earth and moon, the points are located in the plane that includes the earth/moon axis line and the lunar orbit. Each point lies at the apex of an equilateral triangle with the moon and the earth at the other two apexes (see figure 11).

# EARTH-MOON LIBRATION POINTS

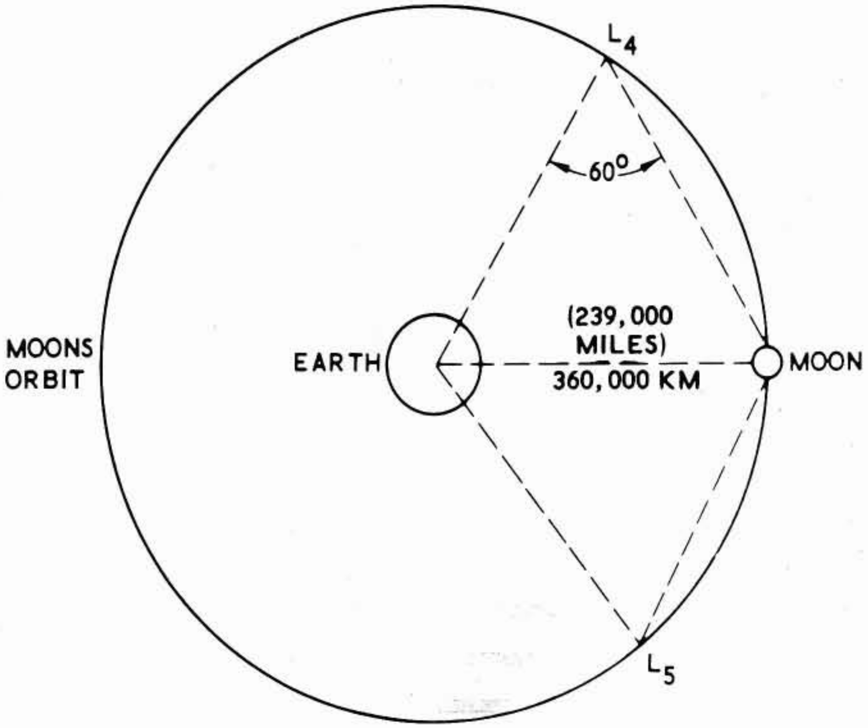


FIGURE 11

Access to earth/moon $L_4$ and $L_5$ would involve space flight from the earth similar to that for a lunar mission, except that there would be an absence of attracting forces as the spacecraft approached the L point.

In a typical mission a satellite would be placed at the $L_4$ or $L_5$ points; this body could persist in stable motion about the earth at these two points. The satellite would provide data on the gravitational fields surrounding the earth and moon and any cyclic phenomena associated with these fields. It might also make measurements to determine the concentration, size, and mass of the possible dust clouds (cosmic debris) centered at this region. These experiments could provide valuable information about the origin of the moon and the solar system.

Satellites located at the libration points ($L_4$ and $L_5$) not only have scientific value, but may also have possible practical applications. These bodies could be used as a communication relay station for deep-space probes or manned landings on other planets, thus minimizing the long distance communication problem. They may also be used as a "warehouse" to store equipment during the establishment of a lunar base.

The standard Saturn V can place 34,000 kg (76,000 pounds) at the earth/moon libration points and the four-stage version, 38,500 kg (85,000 pounds).

## Probes-Out-of-the-Solar System

The next step beyond exploration of the solar system is exploration of interstellar space. This type of mission envisions an instrumented probe boosted to a very high velocity, 16,750 meter/sec (55,000 ft/sec minimum) which will allow it to escape the solar system. This type of probe will provide the first direct study of the interstellar medium. Such probes will collect scientific data on cosmic rays, stellar dust and other galactic phenomena and may provide new clues to the origin and nature of the universe. Also detailed tracking of the orbit of this probe may aid in the determination of additional solar system planets.

The scientific observations that could be performed on a probe escaping the solar system are essentially the same as those on the out-of-the-ecliptic probes. However, instead of observing the interplanetary medium as a function of angle from the ecliptic, the probe will study the interplanetary medium as a function of distance from the sun. These observations would include:

1. Velocity and density of the solar wind and the boundary between the solar wind and the interstellar medium.
2. Neutral gas atoms and molecules.
3. Gradients in the intensity of galactic cosmic rays.
4. Solar cosmic rays.
5. Magnetic field associated with solar wind, both before and beyond solar wind termination.
6. Galactic magnetic field.
7. Intensity and velocities of meteoroids.
8. Search for presence of trans-Pluto planets and planets located beyond Pluto.

The four-stage Saturn V can place 5,750 kg (13,000 pounds) on an extra-solar system flight. However, with this payload weight the flight times to reach beyond the orbit of Pluto are quite large; approximately eleven years. In an excess velocity mission some of the payload could be traded for shorter flight time. For example, if the payload is restricted to 450 kg (1,000 pounds), flight time to the orbit of Pluto drops to 7.5 years.

Thus, the Saturn V vehicle in a three-stage or four-stage configuration can satisfy the complex requirements presented by the goal of scientific exploration of our solar system. The performance of these vehicles is summarized in figure 12.

### Manned Interplanetary Exploration

The Saturn V class vehicle can be used to send men to Mars and Venus in flyby missions. For a typical mission, we have studied the use of the Saturn V in manned planetary exploration missions, employing a six-man spacecraft, flown past the planet Mars in the 1977 time period. This mission involves earth orbit assembly of fueled S-IVB's with a spacecraft whose design is evolved from a Manned Orbital Research Lab space station module and an Apollo command module with suitable mid-course and retropropulsion added.

In the mission envisioned (figure 13), three Saturn V vehicles launch fueled S-IVB's into earth orbit. The S-IVB's are docked with a Support Orbital Dock (SORD) which serves as an orbital docking and checkout station. The SORD provides forward acceleration for propellant settling prior to S-IVB venting. The maneuvering of the S-IVB to rendezvous is accomplished by a jettisonable cryogenic stage made up of hydrogen/oxygen propellant containers and two RL-10 engines (CUSS). After the first S-IVB has entered orbit, the CUSS is removed and the following S-IVB's are launched and mated with the first. A fourth Saturn V launch places the mission spacecraft into orbit. This unit is maneuvered to rendezvous and dock by another CUSS. Thus, the stack assembled in orbit is composed of three S-IVB's, a mission module and a navigation and propulsion module. The hardware in orbit is shown in figure 14. The spacecraft itself is shown in figure 15.

It may be seen that the spacecraft is composed of a probe room, from which Mars experiments are launched during the passage of the planet, a control room containing a bioshield for protection against solar flares during transit, a centrifuge

# TYPICAL HIGH ENERGY MISSION EXAMPLES

| MISSION CATEGORY | POSSIBLE MISSION | | | | | AVAILABLE PAYLOAD (LBS) | |
|---|---|---|---|---|---|---|---|
| | TARGET | ITD | ITT | $\alpha$ | $V_\infty$ | STANDARD SATURN V | STANDARD SATURN V/CENTAUR |
| PLANETARY PROBE | MARS FLY-BY | 1.5 | 150 | 2° | 13,379 | 78,000 | 86,000 |
| | JUPITER FLY-BY | 5.2 | 750 | – | 29,785 | 24,000 | 36,000 |
| COMET INTERCEPT | ENCKE | .4 | 100 | 12° | 30,273 | 22,000 | 34,000 |
| | SCHWASSMANN-WACKMANN | 5.5 | 500 | 9.5° | 41,016 | – | 16,500 |
| ASTEROID | CERES | 2.6 | 200 | 10° | 36,621 | 7,000 | 22,000 |
| | ICARUS | .2 | 80 | 23° | 52,246 | – | 6,000 |
| SOLAR PROBE | | .2 | 80 | – | 43,457 | – | 14,000 |
| | | .12 | 76 | – | 53,223 | – | 5,500 |
| OUT-OF-THE-ECLIPTIC | | 1 | 200 | 25° | 45,410 | – | 12,000 |
| | | 1 | 200 | 35° | 56,641 | – | 1,250 |
| OUT-OF-THE-SOLAR-SYSTEM | | 40 | 4,000 | – | 44,433 | – | 13,000 |
| | | 40 | 4,000 | 10° | 49,316 | – | 8,500 |
| LIBRATION POINT EXPLORATION | MOON-EARTH POINT | 208,000 N. MI. | 100 HRS | – | 13,600 (EQUIVALENT $V_\infty$) | 76,000 | 85,000 |

ITD - INTERPLANETARY TARGET DISTANCE FROM THE SUN (A.U.)

ITT - INTERPLANETARY TRANSIT TIME (DAYS)

$\alpha$ = INCLINATION OF THE FLIGHT PLANE TO THE ECLIPTIC PLANE

$V_\infty$ = HYPERBOLIC EXCESS VELOCITY = $\sqrt{C_3}$

FIGURE 12

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# TYPICAL HIGH ENERGY MISSION EXAMPLES

| MISSION CATEGORY | POSSIBLE MISSION | | | | | AVAILABLE PAYLOAD (Kg) | |
|---|---|---|---|---|---|---|---|
| | TARGET | ITD | ITT | $\alpha$ | $V_\infty$ | STANDARD SATURN V | STANDARD SATURN V CENTAUR |
| PLANETARY PROBE | MARS FLY-BY | 1.5 | 150 | 2° | 4.080 | 35.400 | 34.000 |
| | JUPITER FLY-BY | 5.2 | 750 | – | 9.100 | 10.900 | 16.300 |
| COMET INTERCEPT | ENCKE | .4 | 100 | 12° | 9.200 | 10.000 | 15.400 |
| | SCHWASSMANN-WACKMANN | 5.5 | 500 | 9.5° | 12.500 | – | 7.500 |
| ASTEROID | CERES | 2.6 | 200 | 10° | 11.150 | 3.160 | 10.000 |
| | ICARUS | .2 | 80 | 23° | 15.900 | – | 2.700 |
| SOLAR PROBE | | .2 | 80 | – | 13.300 | – | 6.650 |
| | | .12 | 76 | – | 16.200 | – | 2.500 |
| OUT-OF-THE-ECLIPTIC | | 1 | 200 | 25° | 13.800 | – | 5.800 |
| | | 1 | 200 | 35° | 17.200 | – | 580 |
| OUT-OF-THE-SOLAR-SYSTEM | | 40 | 4,000 | – | 13.500 | – | 5.900 |
| | | 40 | 4,000 | 10° | 15.000 | – | 3.850 |
| LIBRATION POINT EXPLORATION | MOON-EARTH POINT | 385.000 KM | 100 HRS | – | 4.150 (EQUIVALENT $V_\infty$) | 34.500 | 38.500 |

ITD - INTERPLANETARY TARGET DISTANCE FROM THE SUN (A.U.)

ITT - INTERPLANETARY TRANSIT TIME (DAYS)

$\alpha$ = INCLINATION OF THE FLIGHT PLANE TO THE ECLIPTIC PLANE

$V_\infty$ = HYPERBOLIC EXCESS VELOCITY = $\sqrt{C_3}$ M/S

FIGURE 12

S-IVB-1621

## ELEMENTS OF THE MANNED MARS FLYBY PROGRAM

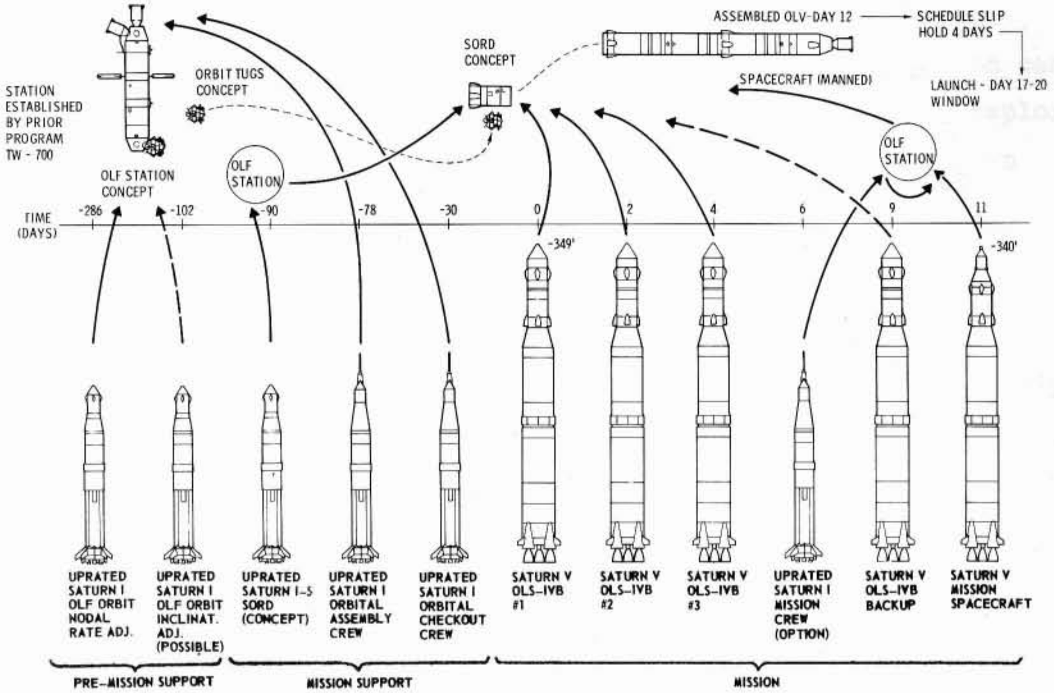

FIGURE 13

S-IVB-1598

## ORBIT LAUNCH VEHICLE AND SUPPORT ELEMENTS

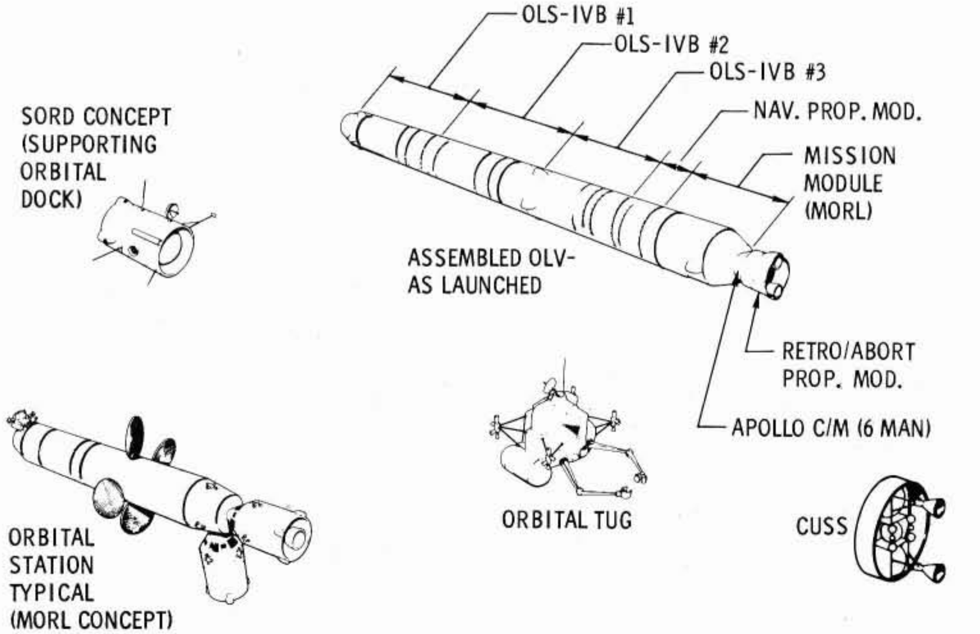

FIGURE 14

S-IVB-1618

## MISSION MODULE SPACECRAFT

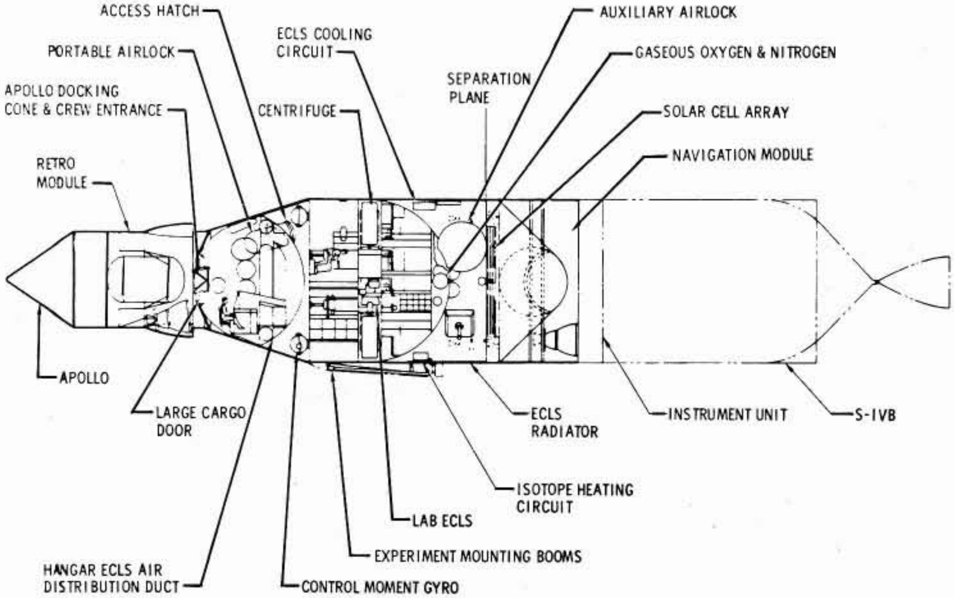

FIGURE 15

S-IVB-1594

## INTERPLANETARY MISSION PROFILE

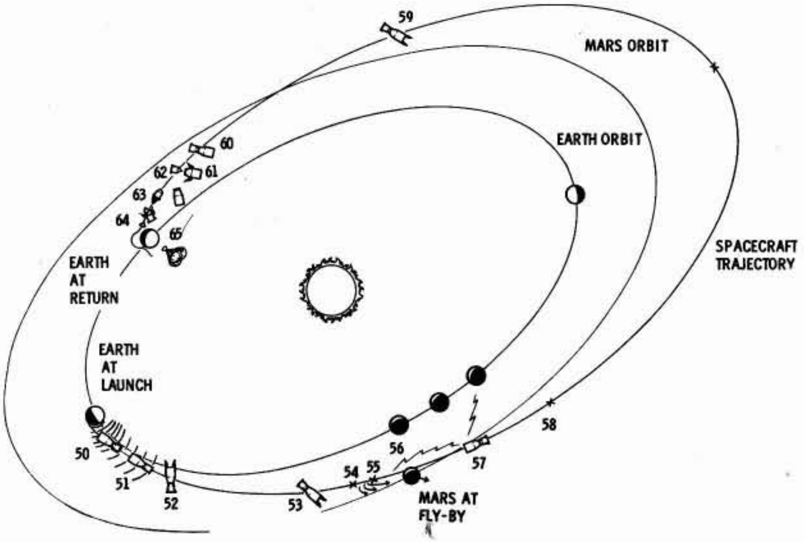

FIGURE 16

for producing periodic gravity exercise for each crewman during flight, and an auxiliary propulsion system for providing mid-course corrections. The Apollo itself is carried with the spacecraft for eventual return through the earth's atmosphere. A retrograde module attached to the Apollo provides braking in the vicinity of the earth. The mission itself is depicted in figure 16. Flight time is approximately 670 days. The scientific observations are conducted throughout the entire flight; the most intensive period of Mars exploration is accomplished during the several days of twilight flyby. After passing Mars, the spacecraft swings out toward the asteroid belt. The recovery sequence of the Apollo spacecraft is similar to that planned for the lunar flight. It is significant to note that in the 1977 time period, the mission described can be accomplished with spacecraft weights approaching 91,000 kg (200,000 pounds). Through the introduction of earth orbit rendezvous techniques, Saturn V can provide a very significant contribution to manned solar system exploration.

The energy requirements of a manned Mars landing appear to require the use of a nuclear upper stage. For this mission, uprated Saturn V first and second stages could place nuclear stages in orbit which could be assembled by the techniques outlined for the Mars flyby mission. Thus, the experience gained in assembling stages for the chemical flyby mission is directly applicable to the landing mission.

## LUNAR EXPLORATION

After the Apollo lunar landing is completed follow-on programs will use the Saturn Apollo hardware to initiate an expanded survey of our satellite. The moon offers the promise to man of the discovery of the mechanism of human and planetary creation. In the lunar subsoil, we may find samples of protolife drawn from the early earth environment. Professor Urey has hypothesized, for example, early deposition on the moon of water from the earth containing primitive life specimens. Knowledge of the volcanic or non-volcanic nature of the moon may shed light on whether the moon originated from the earth or was captured as a passing celestial body.

The moon may eventually offer a platform for manufacturing and research which cannot be easily accomplished on earth or in earth orbit. In the research area, for example, high vacuum on the lunar surface could prove to be beneficial in materials research, heat transfer, thin film technology, welding research, cooling applications, vacuum distillation, super-conductivity, etc. The lunar environment may offer advantages to specialized manufacturing processes, but these will be costly. For example, it is possible to envision manufacturing and assembly of systems near absolute zero involving thin film deposition, vacuum welding, etc. On the backside of the moon, large radio astronomy telescopes would be shielded from the radio noise of the earth, and, if on the dark side, from thermal agitation. An optical telescope of course would not be impeded by an atmosphere and the low lunar gravity would permit use of large apertures. Since the moon rotates once per month rather than once per day, the problem of tracking is much simplified in both radio and optical astronomy. The mass of the moon is great compared to an artificial satellite. Therefore, these delicate scientific installations would not be subjected to aberrations induced by motion of the man in proximity to the instrument. Eventually a lunar station could provide a long term earth communication relay point. Perhaps some day the moon itself might prove to be advantageous as an interplanetary launching site.

With extensive use of the Saturn Apollo hardware in lunar exploration, one can envision new concepts which can add appreciably to the utility of this use. As lunar exploration proceeds the Saturn V vehicle can be used to deliver payloads to lunar orbit and launched in pairs to deliver astronauts and supplies to the lunar surface. An unmanned, cargo-carrying Saturn V, for example, could land almost 13,600 kg (30,000 pounds) of scientific and operational equipment for later use by astronauts landing via LEM.

Information on detailed characteristics of the lunar surface and subsurface structures is needed for the design of the equipment planned for these future programs. Surveyor has already provided certain data on the lunar surface and will supply more in the future; however, its payload capability precludes delivery of significant seismological equipment. Along with Surveyor, the Lunar Orbiter will provide high resolution photographic data on the lunar surface.

Some data should be available from both of these systems late in 1966. Although the Surveyor cannot deliver a heavyweight seismic shock source and recording equipment, it could probably emplace a seismic recorder by 1967, if the shock generation is assigned to another system such as a spent Saturn V/S-IVB stage, impacting on the moon.

The Saturn V begins its flight program in 1967 and will eventually deliver the Apollo CSM and LM into lunar orbit. On such flights, spent S-IVB stages will drift in the vicinity of the moon and could be directed and propelled so as to impact the moon to create a sizable seismic shock (see figure 17). Normally, the stage would have been allowed to drift into solar orbit or returned to earth by controlled re-entry.

If the stage were to impact the moon in a selected area for shock registration in a nearby Surveyor recorder, a moonquake of magnitude 3 on the Richter Scale would be created. The impact could be 160 km (100 miles) distant from the recorder and still provide meaningful refraction seismic data.

These data could provide information on the characteristics of the lunar substructure to depths of approximately 30 kilometers. Such information would be of great value to the development of the lunar subsurface structure models and thus man's knowledge of its nature and history. As an alternate, if the experiment must be delayed until after the Apollo landings on the moon, the seismic recorder could be positioned on the lunar surface in an emplaced Lunar Scientific Station, delivered and positioned by a LM astronaut. Also, in the event that a Lunar Orbiter is in operation at the time of the S-IVB impact, the surface disturbance could also be photographically recorded and transmitted to earth.

The seismic shock provided by the impacting S-IVB stage is equivalent to the explosion of thirteen tons of TNT. The energy is produced by the impact of 15,900 kilograms of empty stage weight traveling at a velocity of 2.56 kilometers per second. The explosive potential of 368 kilograms of possible residual propellants is included in the indicated reaction.

In the normal Apollo flight, the S-IVB propels the Command, Service, and Lunar Excursion Modules into a translunar trajectory. After the Apollo modules separate from the S-IVB stage, they will perform up to three mid-course velocity corrections to insure an optimal lunar orbit entry corridor approach. The Apollo

# SPENT S-IVB STAGE AS A LUNAR SEISMIC WAVE GENERATOR

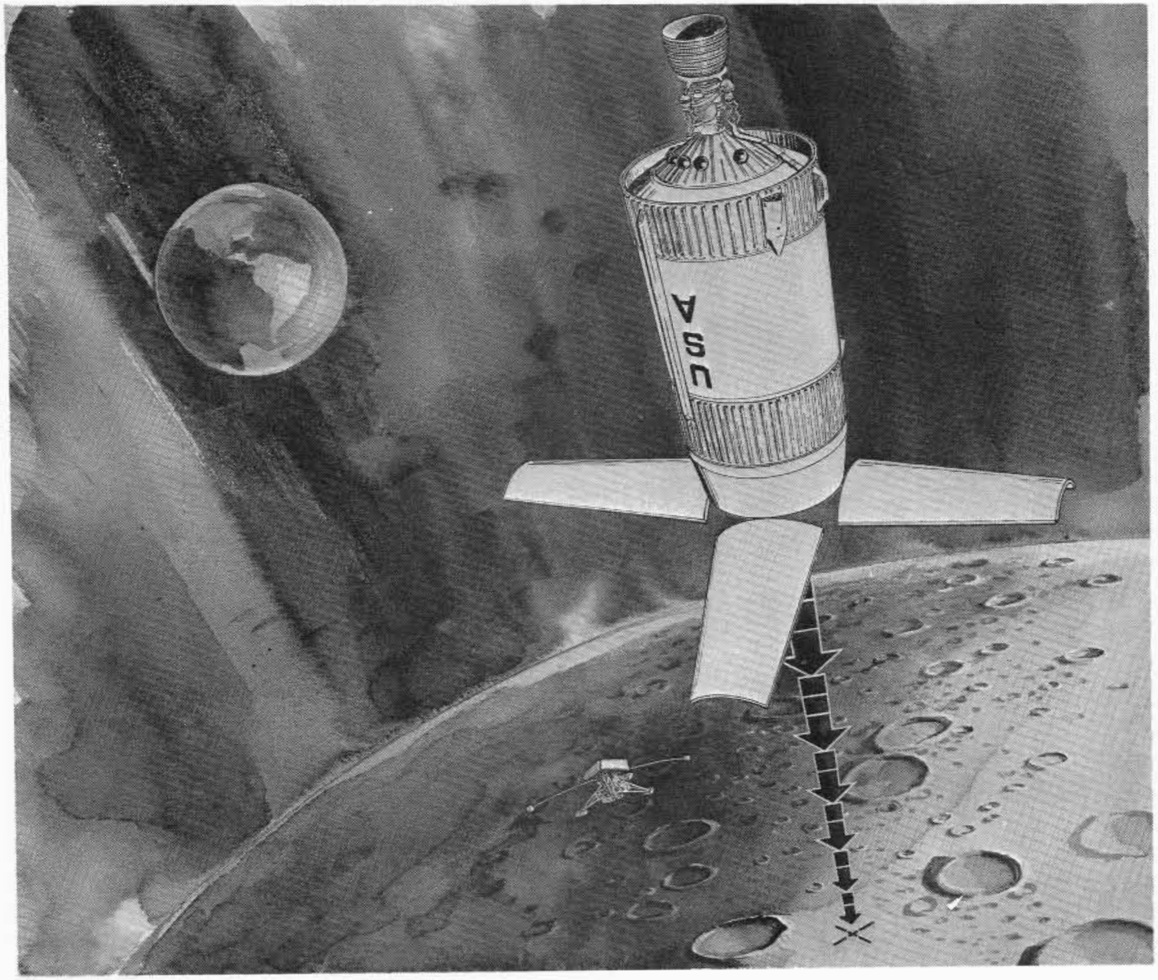

FIGURE 17

modules, therefore, move ahead and away from the S-IVB stage, leaving it to be disposed by some debris control operation.

In order to guide the spent S-IVB stage into a lunar-impact, an initial retro thrust of about 10 1/2 meters per second must be incorporated, followed by several mid-course corrections with the normal stage auxiliary propulsion system under the control of the Instrumentation Unit. In this mode of operation, the S-IVB stage will impact on the lunar surface almost simultaneously with the lunar orbit circularization impulse operation of the Command, Service, and Lunar Excursion Modules on the backside of the moon. It may, therefore, be possible to view or photograph the surface disturbance from the CSM/LM, since they pass over the impact area within an hour after impact.

Thus the Saturn launch vehicle designed for a particular mission, will have utility far beyond that initially anticipated. The tremendous power and versatility of these systems will permit the pursuit of advanced goals in the exploration of space using available resources to a maximum extent. The scope of these future uses will extend from utilization of spent stages through Mars flyby missions and will encompass the solar system. Douglas Missile and Space Systems Division is pleased to play a part in the advancement of world science, through space exploration.